PART B: EDUCATIONAL TECHNOLOGY

> Passion, relationships, fascination, humanity, caring: some teachers will demonstrate the power of these from afar and some from on high. In the coming century we shall discover, and I only hope it does not take too long, that technology's job is to support their choice.

—Tom Snyder (1991)
"What is Great Teaching?" in
Great Teaching in the One-Computer Classroom (Dockterman)

Technology—all kinds of technology, from the TV/VCR to simulation software to microcomputer-based laboratory systems to the Internet—has the potential to enhance and enrich teaching and learning in as many ways as there are creative teachers. David Dockterman's *Great Teaching in the One-Computer Classroom* lists five reasons why teachers may tackle the technology challenge. A computer (and other technologies as well) can help teachers do the following:

- Manage responsibilities and paperwork
- Make dazzling presentations
- Lead incredible discussions
- Manage dynamic cooperative learning activities
- Inspire enlightening self-discovery

Educational technology (as distinct from *technology education*) focuses on learning with technology, rather than learning *about* it. The Office of Educational Technology states,

> Technology is neither an end in itself nor an add-on. It is a tool for improving—and ultimately transforming—teaching and learning. To accomplish that job, technology must be an integral part of the school or community's overall plan to move all children toward high academic standards.

New Jersey's Core Curriculum Content Standards emphasize technology's critical role in the development of science process skills, as well as in nurturing children's problem solving and decision making capabilities. *Standard 5.2* (referred to in this *Framework* as *Science Standard 2*) and its related cumulative progress indicators illustrate the extent to which technology can facilitate and enhance learning: by assisting learners in collecting, recording, analyzing, and presenting data; forming hypotheses; and drawing conclusions—the very skills useful by scientists as they discover and explain the physical universe. *Standard 5.4* (referred to as *Science Standard 4*) focuses on the understanding of technology as an application of scientific principles and technology's role in improving the human condition.

The New Jersey standards also identify the use of technology, information, and other tools among its *Cross-Content Workplace Readiness Standards*, which define the skills necessary for active participation in today's workforce. In light of society's explosive rate of technological innovation and discovery of new information, workers not only need to know more but they also need to know how to learn more and be able to think critically and creatively to solve new problems. In the words of Frank Withrow, the Director of Learning Technologies at the Council of Chief State School Officers, "the United States does not need 'knowers', it needs 'learners'."

How does technology transform the learning process? Consider these examples:

- Through the use of Internet technology, eighth-grade students now study a variety of topics in earth science, physical science, and life science, as well as mathematics, geography, history, and writing, through an integrated exploration of oceanographic and meteorological topics. Utilizing "real-time" data and satellite imagery available on the Internet, as well as electronic communication with oceanographers and other scientists, students experience fundamental science processes and concepts as they formulate solutions to real-world problems. For example, they might figure out how to steer a cargo ship around a dangerous hurricane and then predict the time and location of the ship's destination. With this approach, students are able to use

  - the authentic data available from online resources like NASA and NOAA
  - information from sophisticated instrumentation such as an underwater "robot" that collects and posts current oceanographic data to the Internet
  - electronic collaboration with data from other schools around the world that are conducting similar investigations

- Three years ago, an eighth-grade science class in Jersey City learned about ecosystems by reading about them in their textbook. Today, with the addition of new microscopes and an Internet account, students visit a local freshwater pond to collect samples, analyze them under a microscope, and then establish online communication with classes in Japan, South Africa, and England that are conducting the same investigation. They consider the question, "Will students find the same organisms in the pondwater in these other locations that we do in Jersey City?" Students hypothesize and make predictions about the aquatic organisms of the three locations. By viewing images posted on their partner schools' home pages, they observe that the very same creatures exist in all four sites. In the process, students exchange e-mail about themselves, their culture, and current events. The teacher reports that she has to ask her students to stop writing so much!

- Physics students studying mechanics have traditionally been limited to conducting experiments under a standard set of conditions, such as one "g" and unknown frictional coefficients, while using simplistic and sometimes inaccurate equipment. Now, using a software program called *Interactive Physics*, students simulate difficult-to-perform experiments such as car crashes on dry, wet, and icy surfaces; motion on the moon; two- and three-dimensional collisions; and projectile motion. Students can make predictions, calculate the resulting motion for the given parameters, and check their results by running the simulations. Teachers and students can quickly modify the experiment's parameters to observe the change in results. For example, after calculating the initial velocity necessary to sink a basket from the foul line, students can quickly see how the velocity might change if the angle is changed or if the basketball game were played on the moon. Students can also use this software to increase their understanding of Newton's laws by creating their own simulations that accurately demonstrate each law.

- In the past, students studied the rates of heating and cooling of liquids by using a thermometer to measure water temperature at various time intervals, both as the water was heating up and cooling down. They would record their data and plot the relationship between temperature and time on a graph. Today, building on these experiences using microcomputer-based laboratory systems (CBLs), students collect the temperature at specified intervals. The data is automatically loaded into graphing calculators as the heating and cooling graphs are immediately displayed on the calculator screens. Students also use the calculators to determine a best-fit curve for the data and subsequently the heating and cooling rates (slopes of these lines).

- For years, a fifth-grade class was introduced to meteorology by looking at their textbook's pictures of various weather conditions, watching the weather segment of the evening news, and observing the weather in their own neighborhood. Discussions about unusual weather often led to student-produced artwork. With the integration of videotapes, students were able to experience the velocity of a tornado and the fury of a hurricane. With the addition of the Internet, students are now able to observe movement of weather patterns using real-time satellite and radar images in the same way meteorologists use them to predict the weather. They create a hyperstudio multimedia presentation to demonstrate what they learn about weather.

- Biology students at Manasquan High School used to study organisms strictly with their microscope and textbook. While often effective, this method limited the variety of organisms that could be studied and required that students get supplementary materials from other sources. Although microscopes and texts are still important today, laser videodiscs have revolutionized the learning possibilities. One laser videodisc can store a tremendous amount of information and present it in a full multimedia format. One disc may include video, sounds, text, and software related to a wide variety of organisms. A teacher's presentation provides an exciting and complete resource for leading class discussions and exploration. The discs can assist a variety of learning styles, while guiding individual students through an exploration of the topics and resources presented.

As these examples illustrate, educational technologies can play varied roles in helping science teachers orchestrate the learning environment to their best advantage. For this reason, it is useful to consider technology *not* in terms of its component parts—a computer, a CD-ROM, or a TV/VCR—but in terms of how science teachers employ them in the teaching and learning process. In this context, four categories of educational technology exist:

- **Tutorial technologies**, which essentially perform many of the same tasks that a teacher would, though perhaps in a more efficient manner or with certain subsets of the class (e.g., remediation)

- **Exploratory systems**, which provide enrichment and opportunity for students to investigate, on their own or with guidance, a prepackaged set of facts or information

- **Tool** or **application technologies**, which are used by students in the same way that adults would use them to perform a task in the real world

- **Communications applications**, which provide links between students and others in neighboring schools or with scientists and experts on the opposite side of the world.

The table on the following page describes these four technology categories and lists several examples of each.

CATEGORIES OF EDUCATIONAL TECHNOLOGIES AND SOME EXAMPLES

Tutorial systems are designed to teach by providing information, demonstrations, or simulations in a sequence determined by the system. In this category, the technology does the teaching and controls the information that will be presented to the student. Tutorial uses of technology include the following:

- Expository learning, in which the system provides information
- Demonstration, in which the system displays a phenomenon
- Practice, in which the system requires students to solve problems, answer questions, or engage in some other regimented procedure

Examples:
Computer-assisted instruction (CAI)
"Intelligent" CAI systems
Instructional television
Integrated learning systems (ILS)
Some videodisc/ multimedia systems

Exploratory types of technology applications are designed to facilitate student learning by providing information, demonstrations, or simulations when requested to do so by the student. With exploratory technologies, the student is free to investigate the information presented in the medium. Exploratory applications may promote discovery or guided-discovery approaches to helping students learn information, knowledge, facts, concepts, or procedures. With exploratory systems, students may control their own learning of a discrete set of facts and information presented.

Examples:
CD-ROM encyclopedias
Microworlds/simulations
Some videodisc/multimedia systems
Some hypermedia stacks

Tool or **application** uses help students in the educational process by providing them with the tools to facilitate writing, analyze data, visualize complex systems, and perform other authentic tasks called for in the real world.

Examples:
Word processors, spreadsheets, database management programs
Desktop publishing systems
Calculator-based laboratory systems) (CBLs)
Graphing software
Some applications of Hypermedia stacks (such as for presentations)
Web browser software
Videotape recording and editing equipment
Web page publishing software

Communications applications are those that allow students and teachers to send and receive messages and information to one another through networks and other technologies.

Examples include interactive distance learning via satellite, cable links, ITV networks, and the Internet (e-mail, chat rooms).

The last two categories, tool or application and communications technologies, are called *authentic* uses of technology because science students are using them for the same kinds of tasks and in the same ways that adults would use the technologies outside school walls. Authentic uses of technology have certain advantages over some of the more traditional tutorial or exploratory uses. First, they are more flexible and have the potential for widespread application with different students doing different tasks on different topics. (Traditional uses of technology generally focus on certain subjects with certain students for prespecified tasks such as enrichment or remediation.) Second, authentic applications of technology have the potential to dramatically change the teaching and learning process by putting the student in greater control of his or her own learning.

These authentic uses

- support student performance of an authentic task that is more often complex, multidisciplinary, and challenging
- integrate the technology into activities that are a core part of the classroom curriculum, rather than just a tool for enrichment or remediation
- treat technology as a tool to help accomplish a complex task rather than the subject of study itself
- empower students to direct their own learning and employ the tools that will facilitate their pursuit

Dockterman (1991) identified the following criteria for educational technology:

- *Support of Teacher Control*—Use of the technology must not make the teacher's management task more difficult.
- *Pedagogic Flexibility*—The technology must support the various ways teachers teach.
- *Accessibility*—Teachers must have access to it where they work, both inside and outside the classroom.

Research on the use of technology in science education reports promising results of its impact in promoting constructivist approaches to learning, where greater attention is given to

- higher-order thinking and problem solving skills
- student involvement in higher-level, real-world tasks that integrate a number of basic skills
- student-directed learning
- the presentation of fewer topics in greater detail

Technology provides teachers with new ways to engage students in the learning process through increased opportunities for

- visualization of complex concepts or phenomena
- interactivity with the technology
- collaboration with other classes online with authentic resources in remote locations
- exploration of selected topics in greater depth
- involvement in authentic tasks

Reported outcomes of technology-supported learning include increased student motivation, engagement and persistence, and time-on-task. These factors may underlie evidence that suggests that technology use may be especially valuable to low-achieving students.

Though the reasons for using technology in the classroom are compelling, it would be foolhardy to suggest either that technology is a panacea for improving educational achievement or that implementing technology in the classroom is an easy process. While this Framework section is intended only to define and describe some of the types of educational technology that can be employed in the science classroom, no such document would be complete without at least cursory attention to some of the other critical factors necessary to realize the promise that technology holds to create the kinds of students who can function effectively in the 21st century. These critical factors include the following:

- A technology plan that addresses the school's or district's educational vision and long-term curricular goals, involves all educational stakeholders, plans for initial and ongoing staff development, accounts for costs of initial technology purchases as well as technology maintenance and user support, and provides a means of evaluation and refinement.
- Dedicated time for teachers not only to master the technology but also to determine its optimal uses in the curriculum and adapt and refine their pedagogical strategies and lessons to integrate the technology. In other words, schools must focus on content and pedagogy as well as the hardware and software.
- An interested and supportive administration that can help teachers work through important issues resulting from the introduction of technology in the classroom, including the need for extended periods, new assessment strategies, and logistical challenges of technology access.
- Equitable access to technology by students of all socioeconomic strata, ability levels, gender, and ethnicity, both in school and at home.

So while technology has incredible potential to transform science teaching and learning, it is a complex process requiring not only the support of schools and administrators, but also the persistence, enthusiasm, and tenacity of teachers. In the epilogue of *Great Teaching in a One-Computer Classroom*, Dockterman concludes

> "You can see for yourself that the computer and other technologies are cramming their way into classrooms across the country. . . . As these devices become increasingly available, you have the opportunity to take the lead in the 'revolution.' Steer it in the direction you want to go. . . . don't be an idle passenger who just goes along for the ride. . . . Teachers are the key implementers of education in our country, and if they–meaning you–refuse to accept the challenge that faces them, then the effort, like so many previous reforms, will die."

REFERENCES

Committee for Economic Development, Research and Policy Committee. 1995. *Connecting Students to a Changing World: A Technology Strategy for Improving Mathematics and Science Education*. New York.

Cuban, Larry. 1986. *Teachers and Machines, The Classroom Use of Technology Since 1920*. New York: Teachers College Press.

Dockterman, David A. 1991. *Great Teaching in the One-Computer Classroom*. Watertown, MA: Tom Snyder Productions, Inc.

Glennan, Thomas K., and Melmed, Arthur. 1996. *Fostering the Use of Educational Technology, Elements of a National Strategy*. Santa Monica, CA: RAND

Kemp, Jerrold E., and Smellie, Don C. 1994. *Planning, Producing, and Using Instructional Technologies.* New York: HarperCollins College Publishers.

National Research Council. 1996. *National Science Education Standards*. Washington, DC: National Academy Press.

New Jersey Networking Infrastructure in Education Project. 1997. *Welcome to the NJNIE Classroom Projects Page*. http://k12science.stevens-tech.edu/curriculum/currichome.html

New Jersey State Department of Education. 1996. *Core Curriculum Content Standards*. Trenton, NJ.

President's Committee of Advisors on Science and Technology, Panel on Educational Technology. 1997. *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States*. Washington, DC. http://www1.whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/k-12ed.html

U.S. Department of Education. 1997. *Overview of Technology and Education Reform*. http://www.ed.gov//pubs/EdReformStudies/EdTech/overview.html